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BEST MANUFACTURING PRACTICES

REPORT OF SURVEY CONDUCTED AT

HUGHES AIRCRAFT COMPANY
RADAR SYSTEMS GROUP
LOS ANGELES, CA

JANUARY 1987

BMP

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The purpose of the Best Manufacturing Practices (BMP) survey conducted at this facility was to identify their best practices, review manufacturing problems, and document the results. The intent is to extend the use of progressive management techniques as well as high technology equipment and processes throughout the U.S. industrial base. The actual exchange of detailed data will be between contractors at their discretion. ~~A company point of contact is listed in the report~~

The intent of the BMP program is to use this documentation as the initial step in a voluntary technology sharing process among the industry.

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REPORT OF SURVEY

CONDUCTED AT

HUGHES AIRCRAFT COMPANY

RADAR SYSTEMS GROUP

LOS ANGELES, CA

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I. INTRODUCTION

A. Scope to form 298

The purpose of the Best Manufacturing Practices (BMP) Review conducted at Hughes Aircraft Company, Radar Systems Group was to identify best practices, review manufacturing problems, and document the results. The intent is to extend the use of high technology equipment and processes throughout industry. The ultimate goal is to strengthen the U.S. industrial base, solve manufacturing problems, improve quality and reliability, and reduce the cost of defense systems. → to form 298

To accomplish this, a team of Navy engineers reviewed Hughes Radar Systems Group in Los Angeles, California to identify the most advanced manufacturing processes and techniques used in that facility. Manufacturing problems that had the potential of being industry wide problems were also reviewed and documented for further investigation in future BMP reviews. Demonstrated industry wide problems will be submitted to the Navy's Electronics Manufacturing Productivity Facility for investigation of alternatives to resolve the problem(s).

The review was conducted on 13-16 January 1987 by a team of Navy personnel identified on page 2 of this report. Hughes Radar Systems Group (RSG) is primarily engaged in the design, development, and production of airborne radar systems, weapon control systems, avionics, and related equipment. RSG products (digital signal processing, tactical synthetic aperture radars, active arrays, airborne reconnaissance, surveillance, and multimode/multirole tactical radars) are used in military aircraft as well as space vehicles.

Based on the results of BMP reviews, a baseline is being established from which a data base will be developed to track best practices and manufacturing problems. The information gathered will be available for dissemination through an easily accessible central computer. The actual exchange of detailed data will be between contractors at their discretion.

The results of this review should not be used to rate RSG among other defense electronics contractors. A contractor's willingness to participate in the BMP program and the results of a survey have no bearing on one contractor's performance over another's. The documentation in this report and other BMP reports is not intended to be all inclusive of a contractor's best practices or problems. Only selected non-proprietary practices are reviewed and documented by the BMP survey team.

B. Review Process

This review was performed under the general survey plan guidelines established by the Department of the Navy. The review concentrated on three major functional areas: management, design engineering, and manufacturing. RSG identified potential best practices and potential industry wide problems. These practices and problems and other areas of interest identified were discussed, reviewed, and documented for dissemination throughout the U.S. industrial base.

The format for this survey consisted of formal briefings and discussions on best practices and problems. Time was spent on the factory floor reviewing practices, processes and equipment. In-depth discussions were conducted to document some of the practices and problems identified.

Areas reviewed included design, test, production, transition, facilities, logistics, and management. The team evaluated RSG's policy, practices, and strategy in these areas.

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II. SUMMARY

RSG's application of best practices in design engineering is encouraging. Documented design policy is backed up by detailed guidelines, standards, and engineering manuals. Producibility analysis is a major part of their design process. Careful planning is conducted to permit the use of common components and piece parts across all product lines when possible.

A digital software integrated system has been developed by RSG which enables them to simulate and test radar system software without relying on actual system hardware. They have also integrated CAD into a common engineering data base which supports CAM. To assure integration of all requirements, RSG has established a design review process that includes internal reviews as well as customer reviews. These reviews are conducted early in the process to allow for incorporation of changes.

A major best practice identified at RSG was the attention given to producibility. Six producibility laboratories have been established in various areas of manufacturing to improve the transition from design to production. They are dedicated to determining the producibility of a design and solving potential manufacturing problems. Improved quality, higher yields, less rework, and reduced lead times have resulted from the use of these labs.

RSG employs a number of programs to identify defects, solve problems, and improve quality. The programs are coordinated throughout the group to ensure effectiveness. A key ingredient of these programs is operator feedback. This provides a closed loop process to correct problems and improve quality awareness.

Data collection and management also plays a major role in RSG's operation. Maximum use is made of data collected which is converted into easy to read charts, graphs, and reports for effective use by engineering and manufacturing.

Factory improvements have placed RSG at the leading edge of the defense electronics industry. Investments have been made to automate the low value inventory storeroom, component preparation, assembly, inspection, verification, and test. These developments have contributed to RSG's computer aided manufacturing capability.

RSG has implemented a Total Quality System (TQS). TQS plans and objectives are set by each operating department. The system includes vendor/customer relationships within RSG and internal audits and corrective action procedures. A reduction in the cost of quality has been credited to this program.

The problems identified and discussed at RSG were similar to those identified during other surveys. There are concerns in the areas of design specifications, field performance feedback, piece part control, screening requirements, weapon specification (WS) training, and delays in government acquisition and approval cycles.

III. BEST PRACTICES

The practices listed in this section are those identified by the Navy BMP survey team as having the potential of being among the best in the electronics industry.

A. Design

DESIGN POLICY

RSG has documented corporate and functional area design policies which are backed up by detailed guidelines, standards, procedures, checklists, and engineering manuals. The policies are detailed for the different product areas (i.e., digital, analog, hybrid, software, power supply, RF, wire wrap, PWB, etc.). The standards and guidelines were written by company experts to capture corporate knowledge and incorporate lessons learned. In addition to design policy, each engineering discipline has developed a "road map" for future product development.

DESIGN PROCESS

RSG has a documented design process policy which includes producibility analysis as part of the design and the design review process. Producibility laboratories exist for each major process. They verify producibility and provide the communications link between production and engineering. Trade studies are part of the design process.

COMMONALITY

A Commonality Management Board and Advisory Committee has been formed to establish tasks, set policy, and approve budgets to promote corporate commonality. As a result, the following benefits have been realized:

1. Common components and piece parts.
2. Standards and preferred parts lists.
3. Common modules across three programs.
4. Standard modules packaging, processing, and testing.
5. Common subassemblies (module sets, power supplies, etc.).
6. Common software.

7. Common planning, tracking, inspection, and documentation.
8. Common practices, processes, and assembly lines.
9. Common test equipment, methods, and procedures.
10. Common design tools (hardware and software).
11. Engineering support cost sharing between programs.
12. Common problem solving.

DIGITAL SOFTWARE INTEGRATION SYSTEM

The Digital Software Integration System (DSIS) is a laboratory which enables simulation and test of radar system software. This facilitates real time simulation of the radar software without relying on actual system hardware. In addition, software modules can be integrated and checked out without dependence on hardware.

INTEGRATION OF CAD/CAM

The Radar Design Automation Center (RDAC) is responsible for development, integration, support, and maintenance of existing CAD/CAM systems within engineering. Other services include configuration management, training on application packages and evaluation of new systems and applications.

Engineering computer resources and CAD systems and workstations are on a common communication network. The various engineering data bases, analysis tools, and simulations are integrated within this system.

DESIGN FOR TESTABILITY AND COMMON TEST EQUIPMENT

RSG has a policy that requires up front design for testability. The requirement is carried one step further by requiring engineering to provide the test capability (test requirements, procedures, sectors, and test equipment) as part of the manufacturing process and to verify proper functioning at various levels of assembly. RSG accomplishes this by using common test equipment, procedures, and tapes in the engineering laboratories, producibility laboratories, production lines, and in the field. This eliminates many of the problems found in translating test requirements and methods to different test systems and tester correlations.

COMMONALITY OF PARTS BETWEEN SYSTEMS

An effective configuration management system is employed by RSG to reduce cost and duplication of effort. One result of this system is the practice of establishing, stocking, and using of common parts between products. A

Commonality Management Board, comprised of senior managers and engineers, meets at least weekly to verify common parts between programs and to establish common stockage.

DESIGN REVIEWS

RSG has established the requirement for internal reviews as well as for customer required reviews. A design review coordinator and chairman, who are respected senior personnel, are tasked to review the design data package before the review is held. A design review handbook details the procedure. It specifies that the review (1) be done by qualified technical experts who can challenge the designs and assess risks and (2) be performed as the design progresses. Design reviews cannot be by-passed, must be conducted early enough to effect change, and must be audited to ensure compliance with policy.

B. Production

TOTAL QUALITY SYSTEM

RSG policy states the objective of producing superior products using a strategy of quality first. Each operating organization has a responsibility to generate and operate to a plan to achieve total quality objectives. Achievement is assessed by checking progress toward measurable goals.

The principal elements of RSG's Total Quality System (TQS) are organizational evaluation process, organizational improvement plans, cost-of-quality accounting system, educational/training programs, and feedback and communication loops.

RSG uses an approach in which major organizations are responsible for establishing, confirming, and improving their own product quality. The Group Quality Directorate is responsible for establishing a group wide TQS, assessing conformance of operations to procedures and requirements, verifying product quality through direct examination, and establishing required improvements. The Group and major organizations establish a TQS program, a quality function to support quality related activities, an audit function to assess performance, and corrective action control to assure correction of deficiencies.

The Group also establishes a product verification function to randomly sample completed products and to assess compliance to quality requirements. All organizations have "vendor" and "customer" relationships with inter-working organizations for hardware or services. Each organization audits its own quality and provides corrective action.

INTEGRATED MANUFACTURING PROCESS INFORMATION SYSTEM

The Integrated Manufacturing Process Information System (IMPIS) uses a database, coupled with CAD system workstations, to produce planning books consisting of individual process assembly sheets which include text and graphic instructions. The information contained on the new IMPIS planning is under configuration management at all times based on a standard, validated database.

The IMPIS software is operated on an Oracle database management system with the Sun 3/280 UNIX operating system. The graphics are provided via AUTOCAD and integrated and edited on Sun workstations. Printing of completed planning sheets is performed on a laser printer. ETHERNET is used for interconnection.

IMPIS has been developed according to a four phased plan.

1. Limited pilot production (assembly only).
2. Production (all planning areas).
3. Integrated System (on-line communications with external databases)
4. Optional stage:
   a. Electronic shop floor distribution.
   b. Shop floor process tracking.
   c. Integration with the IMPROVE system (discussed on page 19). check page no.!!!
   d. Integration with labor and attendance data.

AUTOMATED COST ESTIMATING SYSTEM

The Automated Cost Estimating System (ACES) is a computerized system utilized to facilitate preparation of cost information for proposals. It is operated by the estimator, has on-line control and edit capabilities, utilizes day time batch mode processing, and requires Finance Department final output approval. ACES develops a listing of all parts required for the end unit in a sequence that shows what parts go into what. It matches the parts with existing data files of labor hours and material costs, builds a factor file (applies labor rates, overhead, attrition, etc.), and generates a price. Where hard data is not available, the system will estimate the necessary data to provide current and future estimated prices.

PRODUCIBILITY LABORATORIES

In an effort to improve the transition from design to production, RSG has set up six producibility laboratories with experienced manufacturing and engineering personnel. These labs are in the areas of hybrids, PWBs, fabrication,

test and assembly, advanced technology, and, in the near future, microwave.

The labs are tasked to determine the producibility of a design from the engineering department and also to solve potential manufacturing problems. Manufacturing technology projects are also performed in these labs. The interface between engineering and the labs leads to better designs and to solutions to manufacturing problems. Current manufacturing floor equipment and test equipment is used in the labs along with new equipment that is also evaluated there.

Benefits include lead time reductions, reduced rework, field service savings, improved quality, higher yield, and more efficient production. The laboratories have helped RSG to improve and upgrade its production facilities.

JOINT PROBLEM SOLVING TEAMS

RSG has developed a method of dealing with subcontractor problems that is considered a best practice. This method involves the establishment of Joint Problem Solving (JPS) Teams. Teams are established on both a permanent and as-needed basis. RSG has a permanent JPS team of senior personnel that meets twice weekly to determine where "as-needed" teams should be used to help solve supplier problems. The team is made aware of supplier problems by the Material Management Group.

Teams are staffed by the type of personnel that can best address the particular supplier problem. The teams always include a representative from the supplier. These teams, also referred to as "tiger teams," address and focus on the problem and work together to solve it. This unique approach by the "prime" to assist its suppliers strengthens the bond between the prime and its suppliers because they have worked together to solve a problem in the best interest of both parties.

PRODUCT VERIFICATION PROGRAM

RSG conducts a nondestructive teardown inspection of one unit per major program each month to assess product integrity. These teardowns are conducted in accordance with the Product Verification Program. The objective is to verify the system and product by reviewing operating practices, process compliance, hardware, and inspection practices. System verification evaluation topics include corrective action, documentation, machining, test operations, manufacturing processes, and product assurance. Findings can be hardware specific, paper specific, or systemic. These findings can result in tighter controls on processes, planning modifications, update of document

files, operator self check, development of quality trend data analyses, etc.

The Product Verification Program provides rapid high level and operating level feedback. Defects per module have decreased by 31% to 88% on RSG's three major radar programs. These reductions are a result of the teardowns which have yielded better controls and new programs to reduce defects.

DEFECT REDUCTION PROGRAM

Using the principles of statistical quality control and root cause analysis, RSG has implemented a Defect Reduction Program. This program is designed to keep each process within its control limits while improving performance through higher process yields. Feedback to the operator is expedited by continuous review of the data.

Defect Reduction Programs are coordinated with the various manufacturing, product assurance, and engineering disciplines for effective, timely resolution and implementation. Studies are underway to determine the viability of establishing a similar program in the administrative and support organizations. RSG believes it can realize significant gains in these areas.

OPERATOR SELF-CHECK

The operator self-check activity is another way in which RSG promotes operator involvement in the quality assurance function. In this activity, the operator looks at the part he or she is working on before, during, and after the task or operation being performed. The objective of self-checking is to ensure that the operator does not work on, or pass on to the next operator, a defective part. A check list is filled out and travels with the part. The operator now builds and checks the part while the inspector provides useful data regarding what elements of the process to concentrate on to further improve the product and reduce cost.

AUTOMATED CHEMICAL ANALYSIS OF PLATING SOLUTIONS

The purpose of the Automated Chemical Analysis of Plating Solutions (ACAPS) is to replace the traditional methods of chemical analysis of plating solutions for chemicals replenishment with real time instrumental analysis. The procedure is based on a proprietary optrode (sensor) which can withstand the plating bath environment. The optrode has been successful in determining copper and sulfuric acid concentrations in copper plating tanks and peptone and fluoboric acid concentrations in solder plating tanks. The optrode has not been successful in

determining the concentrations of chloride, gleam, tin, and lead. Further work on these has been deferred.

Real time analysis of plating baths will (1) eliminate delays in adding replenishment chemicals and (2) permit operating the baths very close to optimum concentrations at all times and always within concentration control limits. This will improve the quality of electroplated coatings and eliminate PWB scrap due to failures from poor electroplating. In addition to savings from improved yields, there will also be savings due to reductions in manpower and downtime.

COMPUTER AIDED MANUFACTURING NETWORK

RSG has implemented an integrated Computer Aided Manufacturing Network (CAMNET). The initial network was established in 1970 and has evolved into CAMNET version III. CAMNET is based on X.25 and RS232 protocol standards. Since both of these protocols are international standards, almost any system can be integrated into the network. These standards were selected because most manufacturers have products that conform to at least one of these standards.

The CAMNET plan is to tie together the functions of engineering design, manufacturing, and quality assurance. The electronic transfer of data and between these areas will reduce paperwork and increase accuracy.

Various degrees of CAMNET implementation exist. The total effort includes:

1. Manufacturing planning and control.
2. Automated generation of process routings.
3. Inventory control.
4. Computer controlled measurement system.
5. Distributed numerical control.
6. Immediate production verification (IMPROVE).
7. PWB drilling and routing.
8. NC programming.
9. Automated cost estimating.
10. Material management.
11. Automated assembly and inspection workstations.
12. Producibility laboratories.

DATA MANAGEMENT

RSG emphasizes the concept of "turning data into information." This is particularly evident in the inspection area, where a considerable amount of data is generated by automated inspection systems, such as the Zeiss UC850 contact coordinate machine, the View 1200 binary vision system, and the Rank Videomatrix grey scale inspection system. These systems are obviously capable of

generating reams of data which is typically more than can be analyzed in a cost effective manner. RSG engineers make every effort to translate this data into information. This is done by converting raw data into easy to read charts, graphs, and exception reports. RSG personnel feel that their emphasis on this approach leads to more effective process control and, in many cases, results in more timely generation of engineering change notices.

DATA COLLECTION TERMINALS

RSG has implemented a data collection system that is considered a best practice. This system uses the data that is collected by 800 Epic shop floor terminals (one terminal per two work stations). This system depends on 100% use of bar coding of fabrication kits and employees' badges. The system starts when an employee "wands" his badge and the kit bar code. This establishes employee attendance along with the labor charge to the kit and inventory control of the parts. When the employee completes the task, the kit is "wanded" again, allowing the progress of the kit to be tracked and proper charges to be recorded.

Upon implementation of this system, RSG experienced a 10% increase in job charges. This proved to be much more accurate and timely than the previous manner in which charges were recorded. By the use of these data collection terminals, RSG has greatly improved the accuracy of its program management by correct labor charges and inventory control.

ENVIRONMENTAL STRESS SCREENING

The purpose of environmental stress screening (ESS) is to find faults before they occur. RSG applies ESS techniques at the component level, module level, and assembly level. The concept of ESS is to design environmental tests that precipitate defects without degrading the parts.

Parameters were determined by Hughes for the Radar Systems Group and essentially comply with the ESS executive approving panel. RSG believes that the derivation of ESS data is appropriate and hopes to see wider applications.

If properly applied, stress screening and burn-in:

1. Ensure that quality and reliability are built in.
2. Accelerate product maturity.
3. Provide assurance of stable process.
4. Ensure part quality as a predominate factor in screenable defect rate.
5. Drive quality improvement to the lowest applicable process level.

Care is required to achieve a balance between assurance of quality and degradation of service life or reliability.

RSG typically applies temperature cycling and random vibration during most ESS applications. Since ESS has been applied, defects have been reduced by a factor of 10:1.

RSG feels that ESS parameters must be designed to fit each component, module, and assembly in order to optimize effectiveness of the screening and minimize cost.

C. Facilities

AUTOMATED LOW VALUE INVENTORY STOREROOM

A Low Value Inventory Automated Storeroom was implemented by RSG in 1985 to serve all manufacturing areas. Before low value inventory, each manufacturing department was responsible for ordering, receiving, storing, issuing, and trading of parts needed to complete its assemblies. Many of these parts had a unit cost of under $5.00 and were required by more than one department. The low value parts required the same level of control as the more expensive parts, and the duplication of effort by each department was not cost effective.

The new storeroom allows for single procurement, receiving, inspection and test, and storage in an automated storeroom. The criteria for the initial implementation was based on inventory standard hardware, no special handling other than static sensitive, a unit value of $5.00 or less, predictable future usage, and common usage by more than one department.

The procurement of low value hardware is done on a min-max system. Once parts fall below a minimum quantity, an automatic requisition is released for ordering. This requisition is based on one year's usage plus attrition. This allows only one requisition to be placed each year for each part. The increase in parts quality per requisition results in better purchases from vendors.

A major feature of RSG's Low Value Inventory Storeroom is the use of automated storage carousels that move storage containers to a workstation for easy receiving or disbursing of hardware. Another important feature is the use of bar coded labels. A label is generated each time a part is received or distributed from stores. Use of these labels eliminates misplacement and mixing of hardware.

This system has produced savings by reductions in purchase requisitions, purchase orders, storage, and kitting costs. RSG plans to increase the coverage of the low value inventory system.

COMPONENT PREPARATION

The RSG component preparation cell is set up to prep approximately 7800 different part numbers with a throughput of 25,000 components per day. Component preparation involves lead forming, cutting, and tinning operations for axial lead components and flatpacks.

Flatpack lead forming and cutting operations were performed on three identical Hughes designed systems that were highly mechanized and involved special handling tubes designed for use to further transport the flatpacks to the pretinning process. Each tube holds approximately ten flatpacks for loading into the forming and cutting system. Flatpacks are automatically removed from the tubes, and the leads are formed, cut, and reloaded back into the tube.

Each tube is stacked with other tubes in a special clamping fixture. A total of approximately ten tubes (each containing ten flatpacks) are clamped together and then loaded on one of two wave solder machines. The flatpack leads flow across a solder wave and are pretinned. The fixture is manually rotated 180° and reloaded on the wave solder machine for a second pass enabling pretinning of the opposite row of pins. The tubes are then separated for test and routed to the automated placement equipment.

Flatpacks are tested for hermeticity after the solder process. RSG performs a leak test using radiation purging techniques in lieu of the commonly used nitrogen purging techniques because the leak detection is much faster and more reliable.

AUTOMATED PWB ASSEMBLY

RSG has developed a software system (AUTOPADS) that provides an electronic interface between CAD and CAM of PWBs, using surface mounting techniques with formed leads on all devices. AUTOPADS interacts with the automated PWB assembly equipment featuring:

1. Magazine fed (carrier) components
   a. Flatpack surface mount ICs
   b. Axial components
2. Vision system inspection
3. Robotic pick and place
4. Component test of axial lead components before placement

5. Heater bar reflow soldering

AUOTPADS communicates directly with the automated robotic assembly equipment (HPS-300; HPS-400; ALCAS III, and MCAS II systems utilizing an Adept vision equipped robot system) after being down loaded from the engineering database. A computer vision system is used to generate the graphic assembly instructions, including part loading by location, programmable heater bar soldering, automated jumper wire installation, process sheets, and verification film overlays.

CAM/robotic assembly equipment has been developed by RSG specifically for the surface mounting of both flat pack devices and axial lead devices in the producibility lab prior to phasing into production. An eight to one savings in time for assembly has been realized as compared to manual assembly while increasing the quality of the soldering operation.

INFRARED SOLDER JOINT INTEGRITY SYSTEM

The Infrared Solder Joint Integrity System (ISJIS) utilizes and modifies the Vanzetti laser system to detect and classify solder joint defects and quality. Phase II of the ISJIS effort to date has:

1. Optimized laser and IR detector spot size and shape using new optics.
2. Upgraded Nd-YAG laser energy control subsystem.
3. Developed software which recognizes IR lapsolder joint effect signatures.
4. Validated ISJIS effectiveness.
5. Developed hardware and software interface links for ISJIS work cell.

The work cell being developed involves integration of a modified Vanzetti system with a computer aided touch-up station (CATUS), which uses a Swiss Projectina table for automatic positioning of defective solder joints for touch-up resoldering.

Efforts to date show promise for this technique. Integration into production is being planned using 100% ISJIS and varying percentages of (1) visual examination, (2) touch-up, and (3) quality assurance to achieve QA level required with minimum touch-up and hours saved per module being analyzed.

HIGH SPEED MACHINING

RSG has developed new technology to manufacture complex aluminum components with close tolerances, thin walls, and high density aperture paths. For example, the

close toleranced, thin wall (.010 inch) parts could not be economically produced using spindle speeds of 6,000 RPM and approximately four miles of (tool) travel for a specific part using .055 to 5/16 inch diameter "T-slotting" mills. As a result of an Air Force MANTECH study, RSG installed a Matsurra vertical machining center with a 100,000 rpm Bryant spindle, unique vacuum fixturing, and an on-board tool setting (probe) arrangement.

The new Matsurra machining center now produces the same part in a production environment with approximately 1/2 mile of tool travel. The new machining center approach has reduced fabrication time for a set of parts from 6700 hours to 1100 hours. Based on the success of the first system, a new Matsurra system with further enhancements, such as automatic probe check cleaning, automatic tool changing, etc., has been developed and acquired for trial. The new machining system will have thermal compensation. Extensive tool engineering and testing has been performed to evaluate various cutting tools. Thermal imaging has been used to evaluate the performance of various cutting tools along with various coolants and lubricants. Future plans call for integrated machining process control (on-board inspection) and networking of machine systems to separate contact and non-contact (vision) coordinate measurement systems.

AUTOMATED PHYSICAL INSPECTION SYSTEMS

RSG developed a computer aided inspection capability concurrently with the development of the high speed machining systems for complex aluminum components. The coordinate measuring machine systems utilized were Zeiss UC850 and UMC850 machines. The optical vision systems utilized were the Vision 1200 and the Matrix Videometrix. The Vision 1200 is a binary system and the Matrix system is a grey scale system. The machined parts are measured using the best capabilities of the two types of measuring equipment. The data collected from the process has been analyzed with Zeiss "SAM" Statistical Analysis Software and RSG local techniques.

The statistical analysis is performed on HP computer equipment. The data collected is configured into information in an inspection report and given to the high speed machining group for evaluation. The data collection methods are also being integrated with a Brown and Sharp Validator system and an HP graphic system to produce graphic layouts of the parts as well as X, Y, and Z axis deviations from nominal, instead of just X, Y, and Z dimension printouts relating to the engineering drawing. The ultimate objective is to integrate the measurement operations with actual machining systems to achieve process control and ultimately eliminate after the fact or "too late" inspection. The inspection data collected and the analyses performed have resulted in engineering

changes being made to the part drawings, usually loosening tolerances when radar performance has not been degraded by "as machined" conditions. Aspects of this effort have been funded by the Navy MANTECH program.

IMMEDIATE PRODUCTION VERIFICATION SYSTEM

The Immediate Production Verification (IMPROVE) System is a data collection system for product assurance monitoring and control. The system utilizes a Texas Instruments voice recognition module. It is an efficient data collection technique because the inspector is able to input data by voice rather than through paperwork.

IMPROVE provides several advantages. The inspector is more efficient since he/she is no longer required to do paperwork. There is no need to process that paperwork downstream. The data is entered immediately and yields on-line early warning and control limit reporting. This more timely information results in improved yields and reduced scrap and rework.

TEST DIAGNOSTIC ADVISOR

The Test Diagnostic Advisor (TDA) was developed by the Hughes CAM Artificial Intelligence (AI) Group. It is an expert system to aid test technicians in fault isolation during manufacturing test. The system utilizes a Symbolics 3610 computer and Automated Reasoning Tool (ART) software. TDA features fault isolations using a binary search, layout diagrams, schematics, component descriptions, a connectivity display, and expected values for all locations on the board. The program for the first module took ten weeks to develop. It is now being used in a production environment.

TDA is used to troubleshoot double-sided, multilayered boards. The primary benefit of TDA, as any other expert system, is that it makes the knowledge base of an expert available to technicians with lesser experience.

The system has increased the productivity and the accuracy of the test technicians. It has decreased the learning time for less experienced test technicians. It has also reduced the incidence of misdiagnosis and the dependency on senior technicians and test engineers.

D. Logistics

ELECTROSTATIC DISCHARGE TRAINING VIDEO TAPE

RSG uses a video tape in providing electrostatic discharge (ESD) training to all its employees. The tape

is very basic and easy to understand. It points out the many ways that significant, undetected charges can build up on an employee's body or clothing and how these charges can damage electronic parts, components, and systems. The tape also shows the precautions that can be taken to avoid ESD damage. The video tape is a very effective means of communicating critical information to RSG employees in a manner that they can easily understand.

IV. PROBLEM AREAS

A. Design

OBSOLETE SPECIFICATIONS

RSG is concerned with the military's ability to maintain specifications that keep abreast with current technology. As the defense electronics industry evolves to new and improved materials, equipment, and processes, specifications do not often reflect or approve the use of the new technology. To complicate this problem, specification tailoring is not allowed by some of the specifications.

The lack of standards, guidelines, and test parameters in the surface mount technology arena is posing a real problem to RSG. Many military specifications do not address soldering criteria for surface mount components. Many contractors are developing their own criteria based on reliability and process capability. There is no assurance that these criteria will be compatible with military specifications when they are developed.

MIL-STD TRADE-OFFS

Hughes believes size, weight, and cost savings can be realized if contractors perform trade-off studies on compliance with certain portions of various MIL-STDs, instead of designing hardware to meet all prescribed specifications. For example, the size, weight, and cost of EMI filters can be reduced if CE02 and CE03 levels of MIL-STD-461 are relaxed. Similarly, the size, weight, and cost of energy storage devices can be substantially reduced if the loss-of-power and/or undervoltage transients specified in MIL-STD-704 and MIL-STD-1275 are reduced. While full compliance with these specifications should be part of baseline designs, alternate approaches should also be investigated with trade-offs; acceptable performance with size, weight, and cost savings can often result.

B. Test

FIELD PERFORMANCE FEEDBACK

Maintenance performed in the field by military personnel is geared toward replacing failed parts quickly and does not emphasize failure analysis. When failure information is provided to RSG, the cause of failure is often unknown because the amount of information about the failure is insufficient.

RSG recommends field personnel describe the cause of failure as well as the discrepancies and corrective action currently recorded on maintenance action forms. Emphasis needs to be placed on understanding the failure. This data will provide the prime contractor a basis for product improvement which will result in fewer failures in the field.

C. Production

MIL SPEC PARTS

Parts procured to military specifications do not always withstand normal required processing. RSG has experienced softening and degrading of the coatings of RW and RWR resistors during defluxing operations. The resistors are procured to MIL-R-26 and MIL-R-39007 specifications; however, the solvent resistance test called out in the military specifications is not representative of part solvent exposure during manufacturing.

Damaged parts must be removed and replaced at a cost of approximately $2,000,000 per year across all major programs at RSG. Vendors have been contacted but have not been able to resolve the problem. Several protective overcoats are being investigated for application.

A number of instances also exist where suppliers have furnished MIL SPEC parts which have subsequently been shown to be non-MIL SPEC. For example, parts purchased as JANTXV were subsequently found to have had no precap visual inspection performed. RSG believes more stringent controls need to be exercised over parts suppliers.

COMPONENT SPECIFICATIONS

RSG along with most of the contractors surveyed by the BMP team agreed that component specifications need to be improved. Poorly written specifications have resulted in vendor quality problems including component solderability, part marking permanency, and PIND testing defects.

All of the contractors surveyed identified component solderability as a major problem and most believe that better specifications would reduce the magnitude of the problem and in many cases eliminate the problem entirely.

The use of a more permanent ink or a laser in part marking would eliminate the problem of markings washing off during cleaning operations. However, the current specifications do not require it, and the prime can not ask the vendor to apply a different ink or to laser mark the parts without deviating from the specification.

Many primes are finding particles in components by performing PIND tests. This test is not required on non-space components. Therefore, the prime has no recourse with the supplier even though a defect is identified which may cause a system failure in the field.

Another problem cited by prime contractors is their limited role in preparing and reviewing component specifications. A recommended remedy is to involve prime contractors early in the preparation, review, and approval of component specifications.

ENVIRONMENTAL STRESS SCREENING REQUIREMENTS

Environmental Stress Screening (ESS) has had many beneficial results, including reduced failure rates and reduction in overall costs. However, RSG has identified a problem in implementing this requirement. ESS requirements are not standard. Some components require different temperature cycling tests than others therefore requiring different equipment.

Even though some components may require different temperatures, the requirements should be similar enough to allow use of the same equipment. This would result in procuring less equipment to perform ESS leading to cost savings to the customer.

D. Logistics

WS 6536 TRAINING

Obtaining WS 6536 training in a timely manner is becoming a common concern of the defense electronics industry. RSG is experiencing long delays in receiving the training required for its personnel. No alternative to the designated training course is available.

Several recommendations have been made by the industry, including establishing additional training sites and contracting the training out to a support contractor or educator.

E. Management

INTERNAL GOVERNMENT CYCLES

Along with most other military suppliers, RSG is confronted with the delays often encountered when doing business with the Government. The two most common delays are experienced in acquisition cycle lead time and engineering change proposal approval.

Most of industry recommends a streamlining effort to shorten these two processes. Delays often require the contractor to make purchases in advance of a contract using his own funds in order to meet the customer's required delivery schedule. Delays in ECP approval often result in a contractor taking a risk by using a new or modified part or process prior to government approval. Many times the contractor has no choice other than to stop production because the part or process called out in the data package no longer exists.

V. CONCLUSIONS

Many best practice were identified during the BMP survey at RSG. Among the most outstanding were the establishment and use of producibility laboratories and factory improvements.

RSG has developed the capability to prove out a design by producing it in one of their producibility labs using the same type of equipment found on the factory floor. Both design and manufacturing engineers work together in the labs developing and proving procedures, processes, and guidelines prior to release to production. The labs are also instrumental in solving problems and developing new technology.

The organization and utilization of the producibility labs is considered to be somewhat unique in the defense electronics industry. With this capability, RSG has been able to reduce defects, improve quality, shorten delivery lead times, and reduce costs.

Factory improvements are another major factor in RSG's ability to excel in the manufacture of radar systems. Automation has been employed in design, production, inspection, and test areas. CAD/CAM and the integration of data are a key element in the success of RSG's operation.

When off-the-shelf equipment was not available to automate manufacturing and test functions, RSG developed and built its own equipment. Most of this equipment was developed to incorporate new technology. Some equipment has been marketed outside of Hughes.

Many of the best practices employed by RSG are in compliance with DOD 4245.7-M, "Transition From Development to Production." This manual is being used as a guide to evaluate practices being used in industry.

The problems identified during the survey are similar to those identified by the other contractors surveyed. The most significant problem is in vendor quality control (component solderability) and specification requirements. Hughes provided several recommendations for improvement and resolution of some of the problems.

The best practices and problems documented in this report are forwarded to the Electronics Manufacturing Productivity Facility in China Lake, California for further evaluation and research. Some of the best practices will be implemented there and work will be performed to resolve industry wide problems.